Story by Laura Bentz

Editor's note: During the testing and validation or proof of concept state of a research effort, a technology is tested and evaluated in preparation for application. At this point, researchers begin to see if it is feasible for the product to be used on a large scale. AdVE technology is an example of proof of concept work.

A revolutionary desalination technology, invented by a Texas A&M University professor, could give Texas water suppliers a new way to purify water.

Though not yet ready for widescale production, Advanced Vapor-Compression Evaporation, or AdVE, may desalinate brackish and salty water more efficiently and more economically while using less energy than conventional evaporation technology, according to the experts involved in the technology.

This new technology was tested in a pilot project in Laredo. The pilot AdVE project, which opened in August 2010, was funded by the city of Laredo and Terrabon, Inc., a bioenergy technology transfer company.

Because the population of Laredo is rapidly increasing, the city needs to find sustainable ways to provide water to residents. Underground brackish and saline water is available in the area, so the city chose to invest in the AdVE method of creating potable water.

Laredo and Terrabon installed the new technology at the city's Santa Isabel Water Plant. This plant currently uses a reverse osmosis (RO) unit to desalinate water. RO, which uses membranes to filter out the salt, is the most established desalination technology.

How it works

The basic concept behind AdVE is not new.

Dr. Mark Holtzapple, professor in Texas A&M University's Artie McFerrin Department of Chemical Engineering and inventor of the AdVE technology, said its history goes back "at least 60 years, if not longer" and was used during World War II. In fact, according to Dr. Dean Schneider, a Texas A&M Engineering Experiment Station project manager, conventional vapor-compression evaporation is still used on ships today.

The technology uses multiple chambers of water and steam held at increasing temperatures. Each chamber, known as a heat exchanger, separates the liquid salt water from high-pressure steam. AdVE ⇨

Workers watch as the AdVE system is installed at Laredo's Santa Isabel Water Plant. Photo courtesy of the Texas Center for Applied Technology.

PROVIDING PROOF

Desalination technology tested for efficiency, economics

desalination increases efficiency because it adds heat to salty water by compressing steam instead of burning fuel, said Schneider, who is also assistant director of the Texas Center for Applied Technology's Energy and Environmental Sustainability Division.

When the water becomes hot, the steam it produces no longer contains any salt, Holtzapple said. "What you do is take the steam above the salt and put it into a compressor, which raises its pressure and also raises the temperature at which it will condense."

From there, Holtzapple explained that heat flows from a higher temperature to a lower temperature, that is, from the steam to the salt water. The steam then condenses, causing more water to evaporate from the salt water.

Water is removed from each chamber as it becomes distilled. The brine water moves to adjacent heat exchangers, which further concentrates the brine, before it is finally moved out of the system to be disposed.

AdVE is set apart from previous, conventional versions of the technology primarily by two features: a novel heat exchanger and the StarRotor compressor.

Heat exchanger

The heat exchanger used by AdVE is a Terrabon technology, according to Gary Luce, chief executive officer and director of Terrabon.

When developing the technology, Holtzapple said he asked: "What is the required temperature difference to drive the heat across the heat exchanger wall from high-pressure steam to boiling water?" The greater the temperature difference, the more pressure is required by the compressor and the more energy is consumed.

Economically, the answer to this question is vital because energy is the dominant cost in water desalination. Therefore, the goal is to have a low temperature difference, which requires less pressure from the compressor, thereby reducing energy use.

A cost-effective coating on the heat exchanger promotes liquid droplets, Holtzapple said, and this allows the exchanger to push heat across the barrier between the steam and water with a 0.2 degree Celsius temperature difference.

Holtzapple explained how this coating works by comparing it to a waxed car. Normally, rain makes a film of liquid on a car; however, if a car has been waxed, the rain forms beads of liquid on the car. In a normal heat exchanger, the condensing liquid forms a film and acts as an insulator that reduces heat transfer. Holtzapple said an AdVE heat exchanger uses a coating that causes the liquid to bead, which keeps the heat exchanger bare and increases the transfer by a factor of about 20.

"Point 2 degrees Celsius is very small," he said. "That's a very, very small number. The consequence of that is that a very small amount of power is required to do the desalination."

StarRotor compressor

The StarRotor compressor, developed by Holtzapple, is more efficient than conventional compressors and is better suited for compressing steam.

"The compressor has to be efficient from an energy standpoint but also from a capital standpoint," Holtzapple said. "There are a number of technologies that could be used, but we have found that the so-called StarRotor compressor works the best. Although there are many types of compressors in the world, very few of them are suitable for compressing steam, and the StarRotor compressor has shown to be particularly efficient and effective in that job."

One of the "tricks" of the compressor is that water can be sprayed into it while it is operating, he said. Spraying liquid water into the compressor keeps it cool and reduces energy consumption.

Putting it into practice: the Laredo test

AdVE successfully desalinated water at the Laredo plant, but it did not produce the amount of fresh water expected. Schneider said the AdVE-equipped plant was originally expected to produce 50,000 gallons of water per day, but produced only 10,000 gallons per day.

Although this difference was caused by engineering issues, Schneider said, "We did validate that the efficiency of the process still seems to be theoretically possible."

Problems with the seals in the heat exchangers lessened efficiency. "Basically, the endplate gasket was allowing the hot side of the heat exchanger to leak over to the cool side of the heat exchanger," Luce said. "So it was the endplate gaskets that we didn't get good seals on, which was causing problems in understanding what the real heat transfer rate was."

When the gaskets don't seal and liquid water accumulates on the steam side of the heat exchanger, the heated surface area isn't enough for the heat to transfer efficiently, Holtzapple said. "Essentially, the steam side was flooded. This problem should be easily overcome by using a better control system."

"Controlling the bubble point temperature, or the saturation temperature, at the first and last exchanger is another issue we ran into," Luce said.

At the Laredo plant, five heat exchangers were used. For the process to be most effective, thermal efficiency must come from all five heat exchangers. While the middle three heat exchangers produced thermal efficiency, the heat exchangers on both ends were not thermally efficient, the experts said.

One of the favorable findings from Laredo, the experts said, is that the AdVE technology can save money through reducing the amount of waste left from the process by removing more water from the incoming salty water. With any water desalination technology, waste contributes a significant amount of cost to the process.

An added economic benefit of the technology is that very little scaling—which is when salts adhere to the heat exchanger and reduce heat transfer efficiency—occurred on the heat exchangers, the experts said. This is an important observation because scaling is costly to fix, Holtzapple said.

Interpreting the outcomes

The pilot results showed that AdVE is not as cost-effective as an alternative to RO but is useful as a secondary desalination technique to RO, according to Schneider. He said using AdVE secondary to RO would increase water recovery from about 70 percent to at least 95 percent.

Luce explained that as the salt concentration increases, the cost of RO increases also. The cost of AdVE also goes up as salt concentration increases, but not as steeply. Because of this, at a certain point those two numbers intersect and AdVE becomes cheaper. This means that a lot of water can be taken off on the front half by RO and then AdVE can complete the task with the remaining brine water.

By going through this process, more water is recovered and the overall cost decreases.

"Where AdVE is cost effective by itself is in the treatment of high-salinity water," Schneider said. ⇨

The AdVE system was tested to determine if it would desalinate brackish and salty water more efficiently and more economically than conventional evaporation technology. Photo courtesy of the Texas Center for Applied Technology.

This high-salinity water, also known as high-severity service, can contain 50,000 parts per million of salt.

Luce put that number into perspective by comparing it to seawater, which contains about 35,000 parts per million of salt.

Using AdVE on its own for high-severity services, Luce said, has been tested economically but not fully in practice, and therefore its long-term effect on the heat exchangers is unknown.

This ability to desalinate high-severity services differentiates it from RO, which is susceptible to developing problems because its filters cannot handle the high salt concentrations.

Promising future?

"We see a lot of upside associated with the technology, but we need to find a good partner that we can work with," Luce said. "So we're looking for somebody, really in the oilfield services side of the business or a producer that's dealing with frac water, and things of that sort, that we could partner with to really move the technology to the next stage."

Because the experts know how to fix the problems that were encountered, they said AdVE could produce more water at a lower cost if the demonstration is run again with certain modifications.

"I do believe the technology has great promise," Holtzapple said. "I believe that it has significant advantages over current technology. It's not just creating another way to do the same thing. It's better, in my opinion, than what we're doing now."

The evaporator of the AdVE system. Photo courtesy of the Texas Center for Applied Technology.